

~~CONFIDENTIAL~~  
~~SECRET~~

*Summary*  
*7 GR-146*

Mr. Chairzan:

A previous paper estimating and describing Soviet capabilities in geodesy, gravimetry, and cartography has been disseminated to you, and a brief discussion of it will follow my oral presentation this afternoon. In order to facilitate a discussion of the paper now in your possession, it has been suggested that my remarks at this time be devoted to additional background aspects and illustrations concerning the nature of the geodetic problem -- positional and dynamic. In discussing these aspects, I should like to emphasize at the outset that, at the current state of missile technology, it is recognized that the operational error in missile performance substantially exceeds -- possibly by a factor of 10 -- the error in determining the geodetic positions of launch points and targets. With the likelihood of continued technological advancement in missile design and operations, however, it can be expected that the geodetic problem will become increasingly important. Moreover, there are likely to be weapons systems for which the utmost in geodetic accuracy would be desirable. While it may appear premature to consider the geodetic aspect at this relatively early stage of missile development, the complex and time-consuming nature of geodetic-survey operations will require programs -- both U.S. and Soviet -- for years to come. Hence it is hoped that my discussion, together with the paper in your possession, will serve to put some of these operations in their proper perspective with respect to the missile problem.

If this thrusting of the geodetic problem -- and a classical problem, at that -- into a new field of technology already beset

DOCUMENT NO. 2  
NO CHANGE IN CLASS. ☐  
☐ DECLASSIFIED  
CLASS. CHANGED TO TS S  
NEXT REVIEW DATE: 1989  
AUTH: HR 70-2  
DATE 205472 REVIEWER: 006514

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

by more than its share of problems seems somewhat bewildering, it is understandable. A field like surveying and mapping, whose foundations date back to the early history of mankind, might be expected to have its basic house in order by now and to stand ready to serve this newest of man's requirements. Because of its very age, however, the field long ago came to be taken for granted. Surveying of property lines has been practiced since Biblical times and has not presented any significant problems for generations. As modern industrial development progressed and national geodetic systems evolved, these, too, came to be taken for granted. Even within the United States, large-scale mapping of the country is far from complete. International surveying and mapping problems introduced their complications. It took the greatly increased mobility of operations in World War II to bring into focus clearly the inadequacies in and problems created by the existence of different national geodetic systems, each with its own related topographic map coverage. Map sheets of contiguous countries showed displacements in the location of common points at the frontiers, as well as many other troublesome problems resulting from different types of symbolization, differing military grid systems, and, of course, differences in sheet lines. Some of the displacements in positions of common geodetic points, even in Europe, amounted to several hundred feet. One of the major discrepancies developed between the Soviet Pulkovo system and the German Potsdam system; this is now being resolved in the European Satellites under Soviet sponsorship. If these displacements were tolerable in the past, it probably was due solely to the fact that artillery fire could

- 2 -

~~SECRET~~~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

be observed and corrected for greater effectiveness. But the limitations of this technique and the impossibility of applying it to modern problems are emphasized by missile positioning, which involves distances many times greater and widely separated geodetic systems still not satisfactorily related. Ignoring for the purposes of this analysis the relatively much larger operational errors inherent with missile flight caused by aerodynamic and mechanical factors, the question arises as to the relative geodetic positioning accuracy between a launch point on one continent and the target located on another. This question is now discussed only in terms of Soviet capabilities and the currently indicated Soviet trend and progress in achieving a world geodetic system.

Let us, then, examine in somewhat greater detail the underlying characteristics of the Earth as a geodetic body with respect to both the positioning problem and the dynamic effects of gravity on a missile in free flight.

If we are to survey a small area, such as a piece of property, we can treat the area as a plane, ignoring the curvature of the Earth's surface. The determination of points in relation to each other is, then, a simple problem in plane geometry and trigonometry. For larger areas, however, the curvature of the Earth must be taken into account, and we must resort to analytical and spherical trigonometry. If the Earth were a sphere, the problem still would be relatively simple since we would need but a single parameter, "r", the radius of the sphere. The location of any point would be expressed by latitude and longitude, i.e. by the angular distance both from a prime meridian and north or south of the Equator to the point in

- 3 -

~~SECRET~~~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

question. The Earth, however, is not a sphere but an irregular figure not unlike a slightly squashed orange -- flattened at the Poles, with a compensatory (but not entirely regular) bulging at the Equator. Thus our problem becomes more complicated by the substitution for "r" of two other parameters: "a" for the Equatorial radius (or semimajor axis) and "a" (alpha) for the flattening. Now we have two of the five parameters necessary to establish a geodetic network of reference points, to which supplementary and lower order control can be related. This dense network (together with a leveling net that provides elevations of all points) serves as a skeleton around which a topographic survey references physical and cultural features that find their final expression on topographic maps. A basic or first-order geodetic system begins at an initial point, for which the geodetic latitude and longitude are precisely determined. This gives a point of origin from which to expand our geodetic system. We also need an azimuth (capital "A") to some selected point for the orientation of our system. Finally, an ellipsoid of reference with agreed-upon values for the Equatorial major semiaxis and flattening provides a regular surface along which the computations for the subsequent points of the network are made. Thus, these five quantities -- latitude, longitude, azimuth, Equatorial radius, and flattening -- determine the distinctive characteristics of a geodetic datum or system. A change in any one of these quantities changes the datum. If there were but a single initial point and if the same Ellipsoid of reference were used by all countries, the computed coordinates of any two points would be comparable with respect to one another.

- 4 -

~~SECRET~~~~CONFIDENTIAL~~

**CONFIDENTIAL**

and we would, in effect, have a world datum. Such, however, is not the case. Many different geodetic systems have evolved as national systems, using different ellipsoids of reference, different initial points, and distinctive orientations of the ellipsoid to the geoid. As a result, these different systems have given rise to displacements between common points at the frontiers. Even within the relatively small area of Europe the displacements have been significant. Between the German and Danish system the discrepancies amounted to 6."4 in latitude (or 640 feet) and 8."9 in longitude (or 500 feet); between the Danish and Swedish systems, 0."4 in latitude and 5."5 in longitude; and between France and the United Kingdom, 5."4 in latitude and 4."0 in longitude. To resolve these differences is not easy, particularly over longer distances and across large ocean bodies. To explain this further, it is necessary to refer to still another concept, the geoid. Earlier, five quantities were described as comprising a geodetic datum. It is necessary now to recognize that our geodetic observations are made on the Earth's surface -- with all its irregularities, valleys, and mountains -- whereas the computations are made along the regular geometric surface of an ellipsoid of reference. Moreover, an observation made on the Earth's surface is made by an instrument which is perpendicular or normal (established by a plumb bob or bubble) to the surface at the point of observation. Actually, the observed values must be reduced for elevation to the geoid, which is defined as an equipotential surface at mean sea-level. This means that the potential of the gravity force is constant on this surface and the force of gravity is everywhere perpendicular to it. The geoid

- 5 -

~~SECRET~~**CONFIDENTIAL**

~~SECRET~~  
CONFIDENTIAL

deviates from a mathematical surface and reflects the heterogeneous distribution of visible and invisible masses in the Earth's crust.

The wavings or undulations of the geoid can be calculated for a particular ellipsoid, provided gravity data covering the Earth are at hand. Changing the ellipsoid will also change the representation of the geoidal undulations. The task of the geodist is centered primarily on finding the relationship between the three surfaces: the Earth, the geoid, and the selected ellipsoid of reference.

The undulations of the geoid further mean that at any point on the Earth's surface the direction of the force of gravity and the normal to the ellipsoid will vary by a very small angle called the station error or deflection of the vertical. This generally is only a few seconds of arc, but in mountainous regions it may attain a value over  $1\frac{1}{4}$  minutes of arc, causing a horizontal displacement of position up to 7,500 feet.

Depending upon the approach in ascertaining the deflector angle, the geodist further distinguishes between relative and absolute deflections of the vertical. Relative deflections are obtained by reducing to a minimum, using the least-square method, the small differences between astro-coordinates and the calculated coordinates of a control point in the horizontal net of a geodetic system. Absolute deflections, on the other hand, are obtainable only from a systematic gravity survey of the whole Earth and the application of the Stokes and Vening-Meines formulas. Such a survey, incidentally, is still far from complete. The gravity deflections are considered as absolute because the calculations are based on the assumption that the center of the ellipsoid coincides with the center of mass of the Earth,

- 6 -

~~SECRET~~

CONFIDENTIAL

**CONFIDENTIAL**

that is, the ellipsoid is ideally placed with respect to the Earth's axis and center of mass. Assuming that geoidal undulations have been determined, it is possible to calculate the tilt between the geoid and the ellipsoid of reference and thus obtain absolute values of the deflection of the vertical. With this, the initial points of various geodetic systems can be corrected, and all astro-triangulation points converted to a common value, in this way linking all geodetic datums and all related topographic maps to a common reference system. Similarly, for areas devoid of triangulation, astronomic positions can be corrected for deflections of the vertical, thus converting them to geodetic positions on a common world system. To a unique degree, the Soviets have stressed the gravimetric approach to geodetic problems. They have gravimetrically determined, with great accuracy, the components of the deflector angle at their initial point, the Pulkovo Observatory, and then projected their control net upon the Krasovskiy ellipsoid, which is separated by only a few meters from the geoid at Pulkovo. This is known as the "Pulkovo 1942" datum, and has replaced "Pulkovo 1932" based on the Bessel ellipsoid. The Soviets had bitter experiences as a result of the inadequacy of their geodetic datums and triangulation, which were based on a poorly fitting and improperly oriented ellipsoid. In 1936 the Soviets discovered a discrepancy between their two major datums amounting to displacements of 900 meters between points common to both. By carefully working up the application of some of the basic gravity work developed by Stokes and Vaning-Meiness, the Soviets have succeeded in adding rigor to their geodetic datum through the use of gravity data, which have at the same time been of great

- 7 -

**SECRET****CONFIDENTIAL**

~~CONFIDENTIAL~~

value to basic geophysical studies and mineral prospecting. Quite understandable, therefore, is the insatiable Soviet quest for more of the Earth's gravity data.

The Soviet drive for gravimetric data began in 1932, with a systematic survey providing for a minimum of 1 observation point per 1,000 square kilometers of area, including gravity-data observations in the Arctic Basin. Simultaneously, the Soviets have been collecting foreign gravimetric data, which by 1951 totaled 25,000 determinations. To step up its collection of foreign gravity data the USSR initiated suggestions for an expansion of gravity observations in the program of the International Geophysical Year, even though such observations are not strictly within the synoptic concept of the IGY. It is significant to note in this connection that the effort to step up gravity work is to apply only to areas outside the USSR -- first, in Antarctica, for which gravity data are largely lacking, and second, in a loop connecting the North Pole, through Continental USSR, with India, Southeast Asia, China, and Tiksi. The resulting data will represent an important addition to the Soviet foreign gravity collection and becomes especially significant strategically by virtue of the Soviet denial of its own vast amount of gravity data to the Free World -- including India. With such an expansion of the basic Soviet gravity network, the Subcontinent of India, and the remainder of Southeast Asia becomes tied gravimetrically to the Soviet Union. In contrast the Free World is deprived of the vast Soviet data, and the Soviets can safely boast that they hold more gravity information than does the rest of the world combined.

- 8 -

~~SECRET~~~~CONFIDENTIAL~~

~~CONFIDENTIAL~~

Simultaneously with the gains to geodetic positioning, the gravity-anomaly maps required for a world geodetic system will also be of value to the dynamic geodetic problem. With some exaggerations, the diagram illustrates the currently estimated possible effect of the gravity field on the theoretical ballistic path of a missile in free flight. Here again, it appears that the Soviet gain from its aggressing gravity activities may be compounded with the passage of time. At present the major deterrent to the completion of a world geodetic system by the US and the USSR is the inadequate gravity coverage over the vast oceanic areas, which can be obtained only by time-consuming observations in submarines. Here, I am happy to say the US has achieved something of a break-through by the development of an instrument which reduces observational time from about 4 hours per value to about 5 minutes.

Finally, may I briefly summarize our estimates of Soviet positioning capabilities, which are treated in somewhat more detail on pages 12-17 of the report now in your possession.

The estimates are given for three different cases.

- (1) In the first case, we assume that the Soviets have made a connection across the Bering Strait. With this connection the Soviets, having the basic US data, could establish a launching site within the USSR on the North American Datum. Under such conditions the Soviets, with their capability for achieving an accuracy of 1:100,000 for long arcs in their triangulation, could then attain a CEP of 300-500 feet against Canadian and US targets.
- (2) In the second case, we assume that there is no connection. Then the whole range of problems due to datum uncertainties,

- 9 -

~~SECRET~~

~~SECRET~~  
CONFIDENTIAL

Differences in parameters of ellipsoids and their orientation, and calculation of the deflection angles and geoidal heights will make it doubtful whether a CEP better than 1,000 feet can be achieved. However, if the Soviets are developing a Solar Eclipse program or other celestial triangulation programs, the CEP may by 1965 be reduced to 200 feet, regardless of a connection.

(3) The third case is the European. It is estimated that the CEP capability is now 200 to 300 feet. The capability is being strengthened by a program imposed by the USSR on the European Satellites to convert their datums and maps to the Soviet datum and mapping system. The estimated date for completion of the major field work and mathematical readjustment is 1957.

- 10 -

~~SECRET~~

CONFIDENTIAL